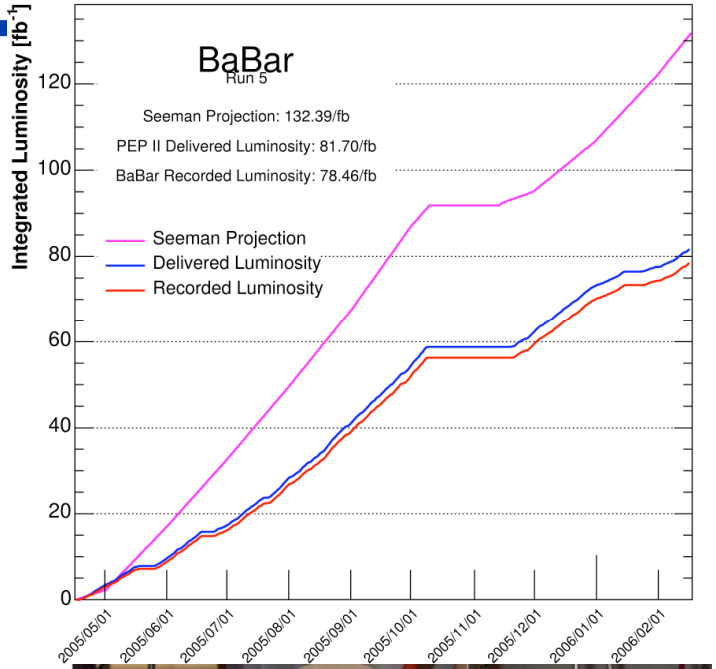
BaBar

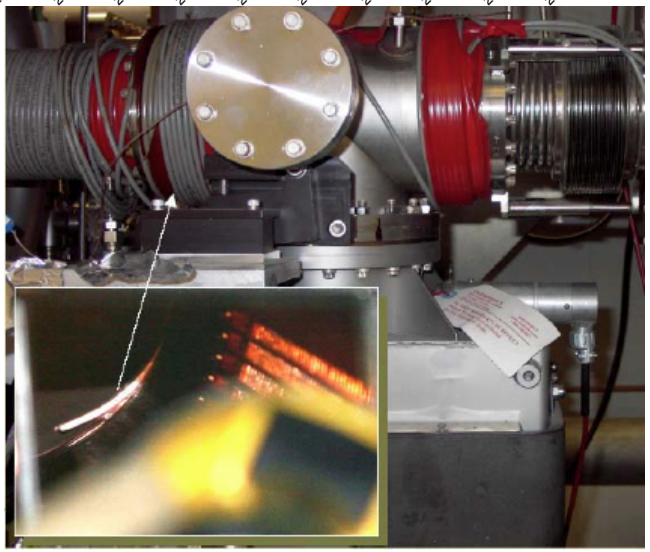
David Brown

March 2, 2006

Status of BaBar & PEP II

- Beam blowup limits LER current
  - — 1 problem found and fixed, at least 1 other remains
    - LBL's Steve Dardin on standby!
  - — PEP II Instantaneous luminosity ~40% of achieved maximum
  - — ~400 fb^{-1} in summer 2006 vs ~500 fb^{-1} projected
- KEK-B running smoothly at ~3X PEP II luminosity
  - — ~600 fb^{-1} in summer 2006
  - — Crab cavities?
- BaBar, Belle ~equal in paper submission, quality, and significance of results
- P5 report final, not yet released
  - — 'positive' about BaBar
- R. Staffin comments to BaBar IFC indicate DOE funding through FY 2008



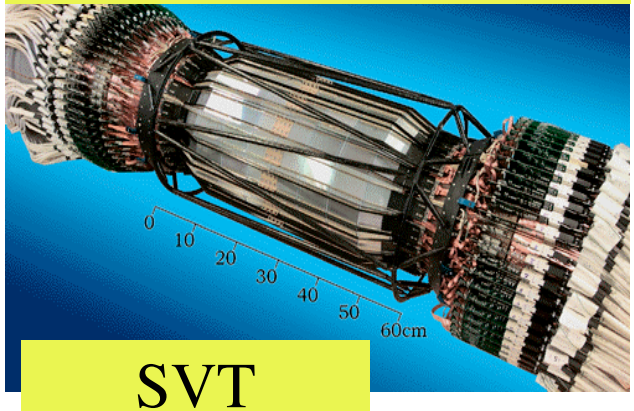


The LBNL BaBar Group

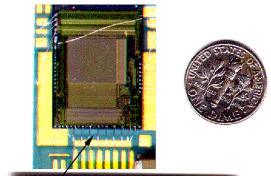
	October 2005	October 2006 (plan)
Faculty & Staff	Marco Battaglia Bob Jacobsen Yury Kolomensky David Brown Robert Cahn ~3 FTE	Marco Battaglia Yury Kolomensky David Brown Robert Cahn ~2 FTE
Post-docs	Andrei Gritsan David Lopes-Pegna Lluisa Mir	David Lopes-Pegna
Grad Students (prospective) (Graduated)	Yury Groysman Gena Kukartsev Toyoko Orimoto Kerstin Tackmann Mandeep Gill	Kerstin Tackman Tomohiko Tanabe Ilya Osipenkov
NERSC	Igor Gaponenko (0.75 FTE) Paid by BaBar common funds	Igor Gapnonenko (0.5 FTE) Paid by BaBar common funds
Retirees	Leroy Kerth Gerald Lynch	Leroy Kerth Gerald Lynch
Visitors	Christoph Anders Elisabetta Prencipe	
Undergrads	Adrian Down, Zac Judkins, Peter Koo, Jesse Reiss, Aritoki Suzuki, Dan Troost, Chris Williams	

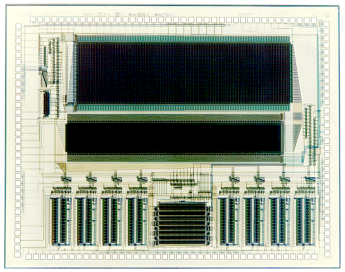
LBNL's Contributions to BaBar

Silicon Vertex Tracker



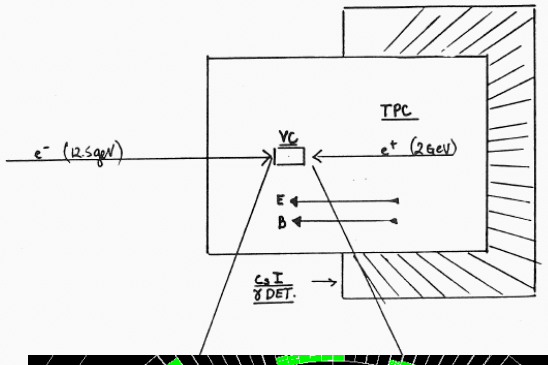
SVT Readout IC

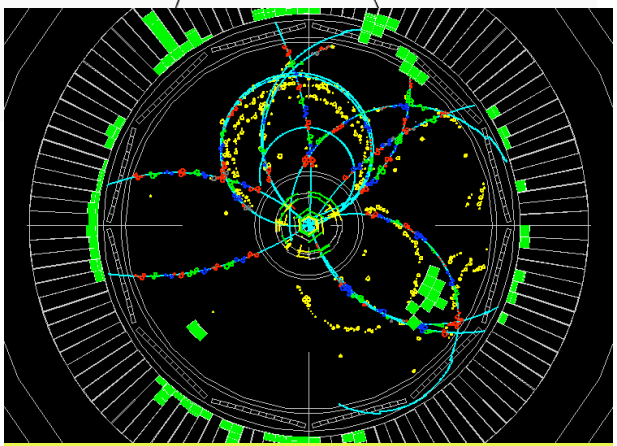




Drift Chamber Readout IC

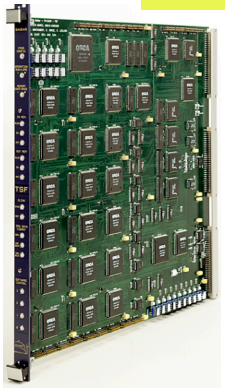
Asymmetric B-factory concept

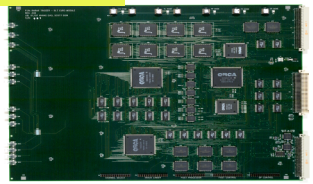


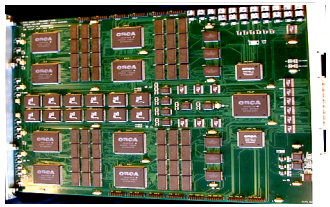


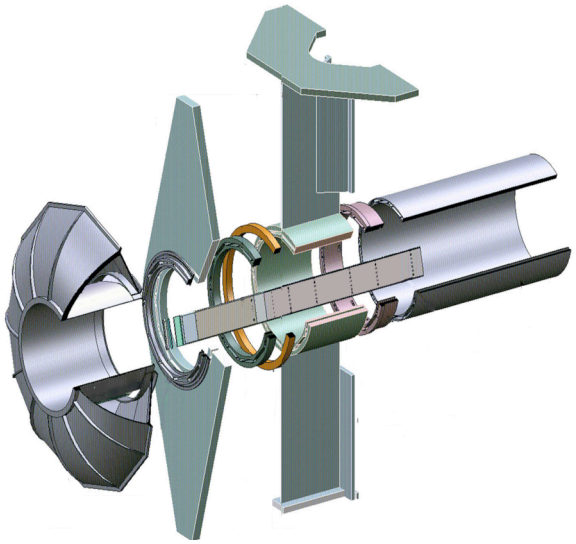
Computing and Software

Trigger





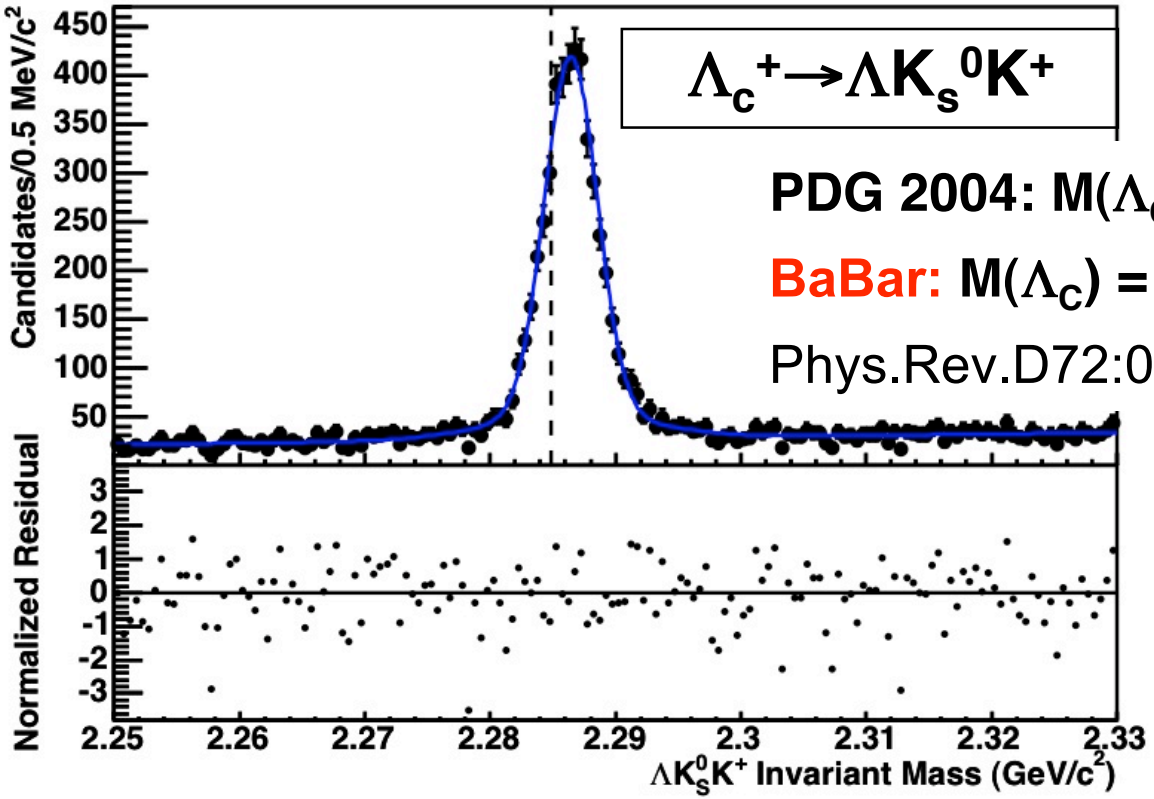




DIRC

Computing Model 2 (deployed 2003)

- Replaced Objectivity with Root-based event store
- Introduced a new data format which …
  - — Provides access to detailed detector information
  - — Allows users to customize event data for their analysis
- LBNL provided concepts, design, implementation, and leadership



PDG 2004: $M(\Lambda_c) = 2284.9 \pm 0.6$ MeV/c²

BaBar: $M(\Lambda_c) = 2286.46 \pm 0.14$ MeV/c²

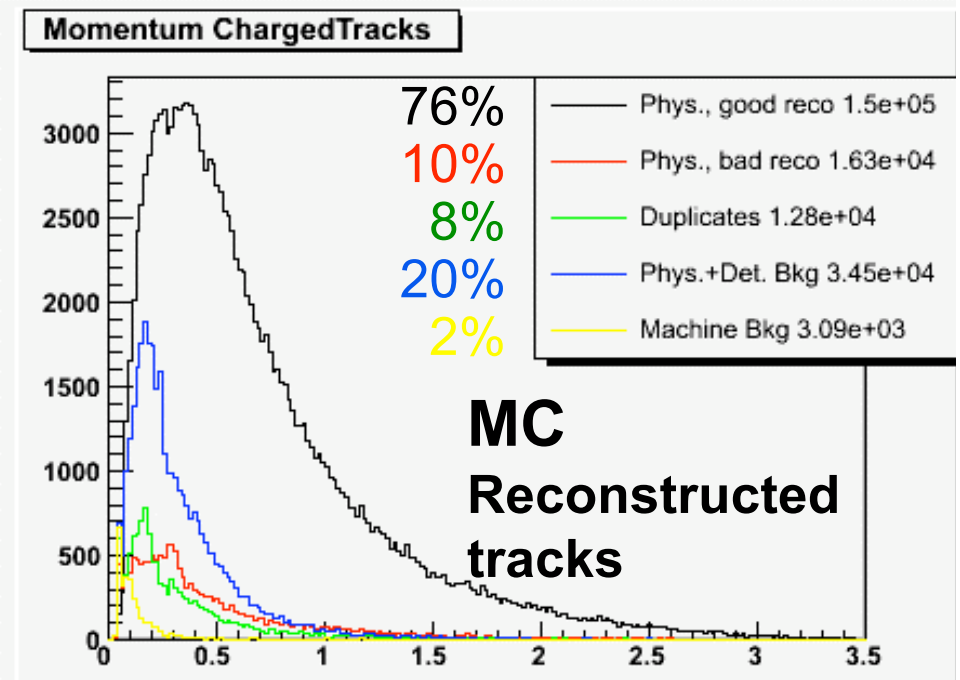
Phys.Rev.D72:052006, 2005

Improving BaBar Tracking

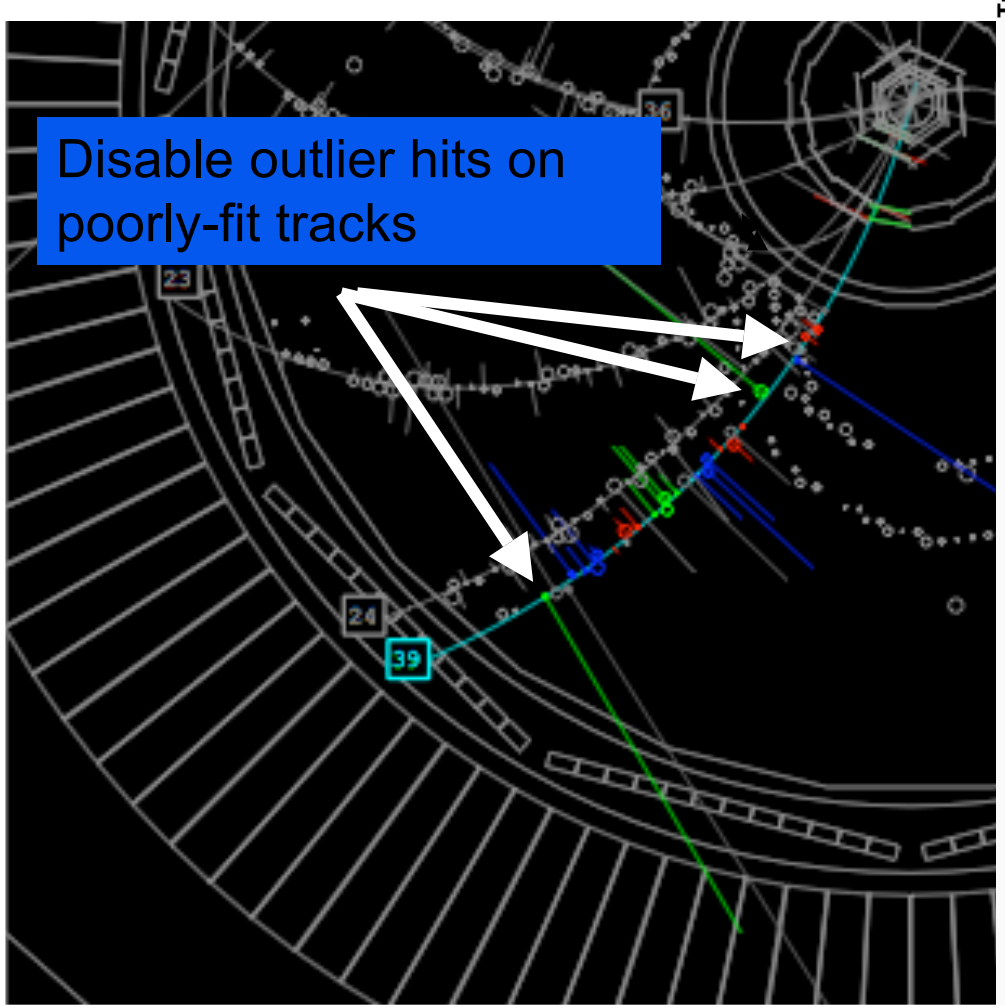
- **LBNL has initiated an effort to improve tracks in analysis**
  - **Tracks are the core of most BaBar analyses**
  - **Average track multiplicity of B event is ~10**
    - **Small improvements can add up to substantial effects**
  - **Improved track efficiency & resolution = 'free luminosity'**
- **CM2 data format provides essential detector data**

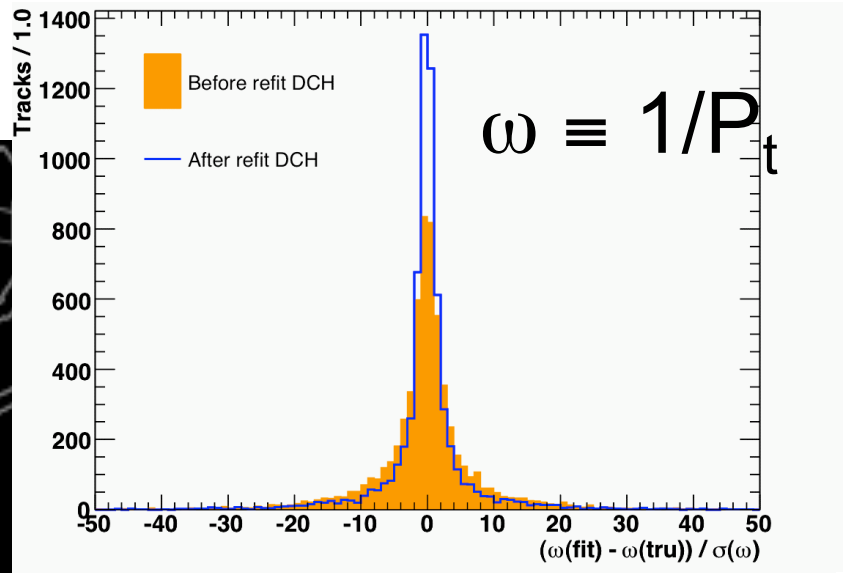
MC tracking study

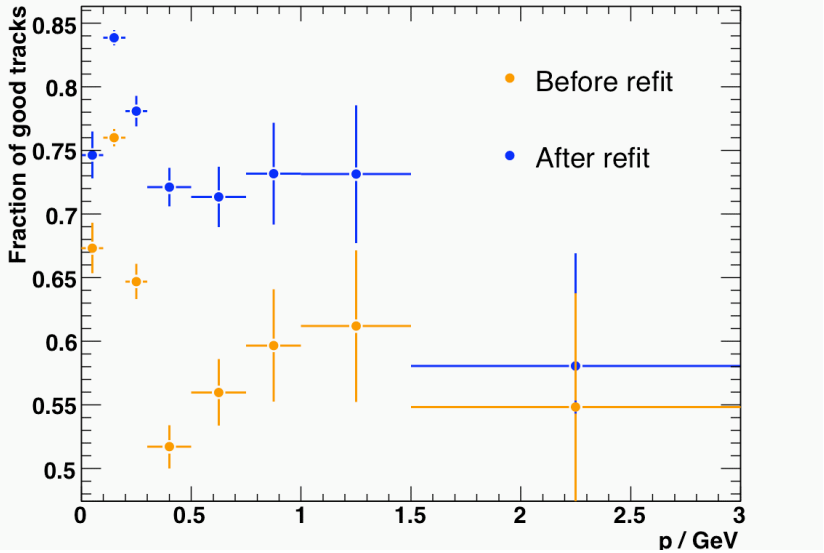
- 76% good track efficiency
  - 11% angular acceptance
  - 10% bad reconstruction ('pull' > 10σ)
  - 3% Pat. Rec. inefficiency
- 30% fake tracks
  - loopers, decays, …



Cleaning up Hits

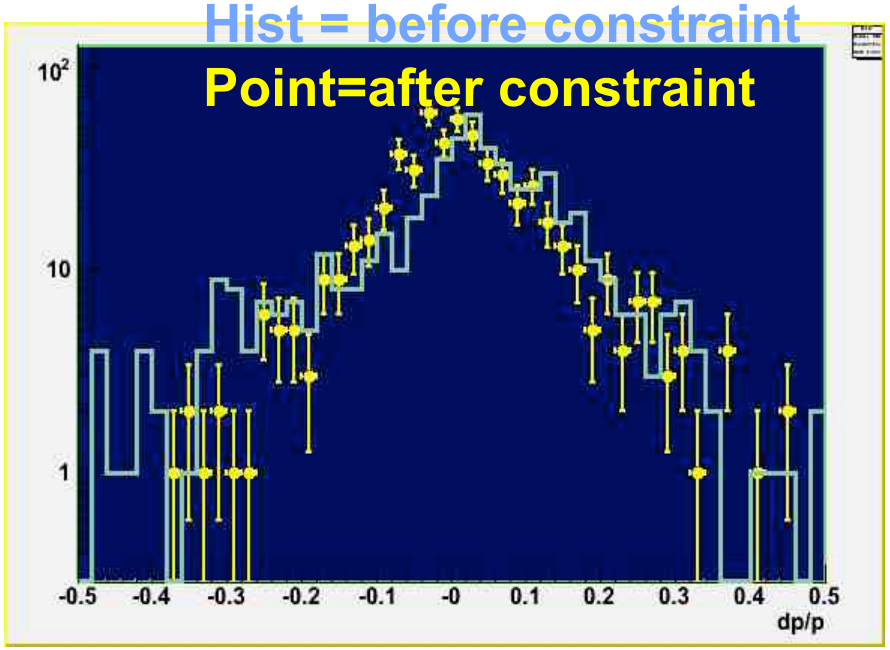


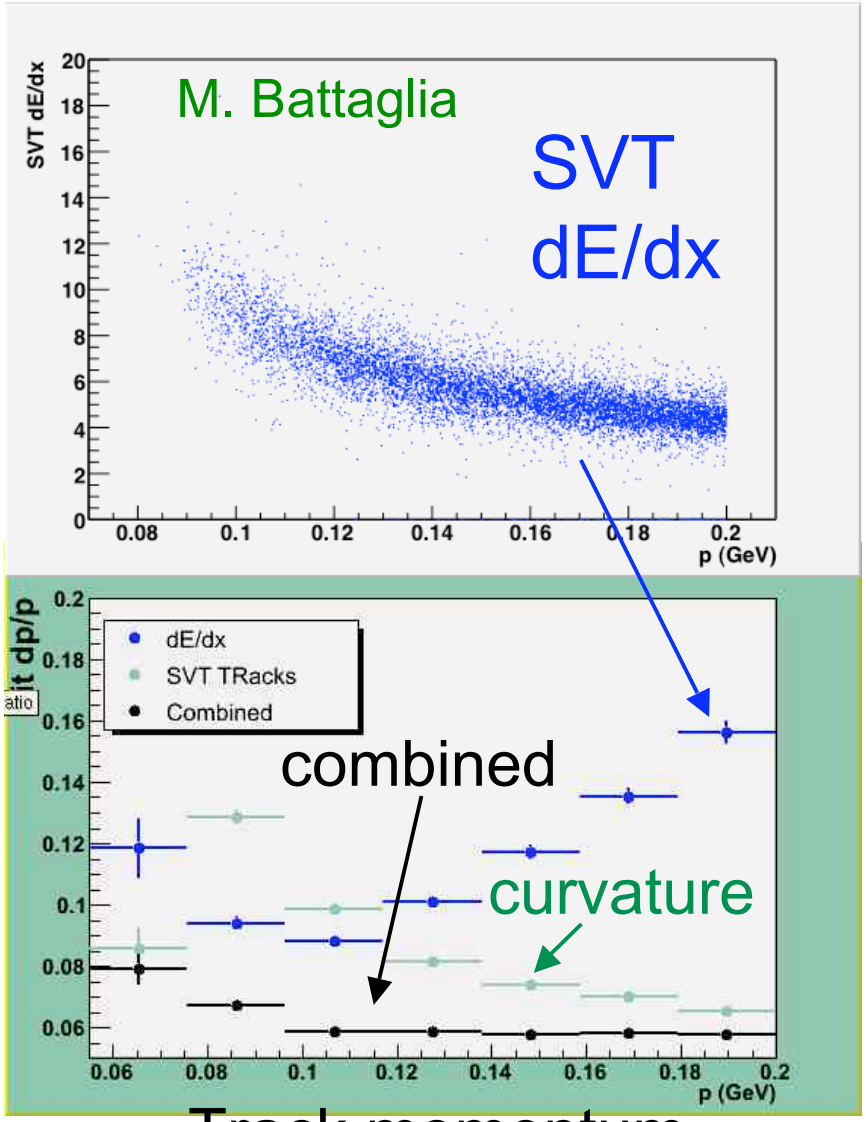




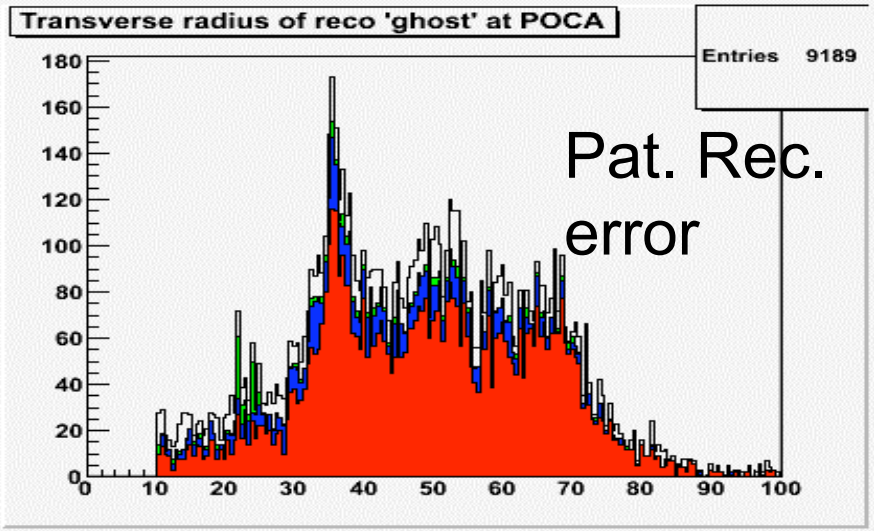
SVT dE/dx Constraint

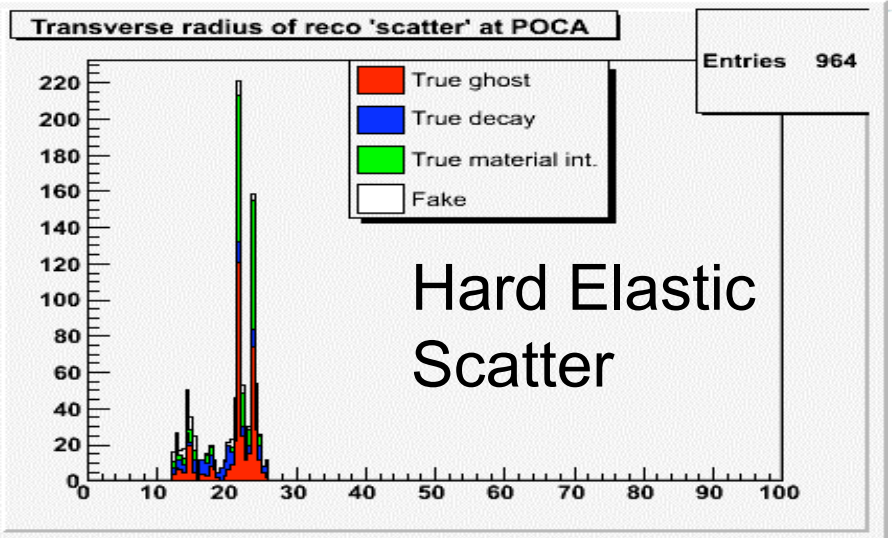
- Constrain momentum using inverting Bethe-Block curve
- Competitive with B-field curvature at low momentum
- Makes δP/P ~ flat vs P at <5%
- Reduces outliers

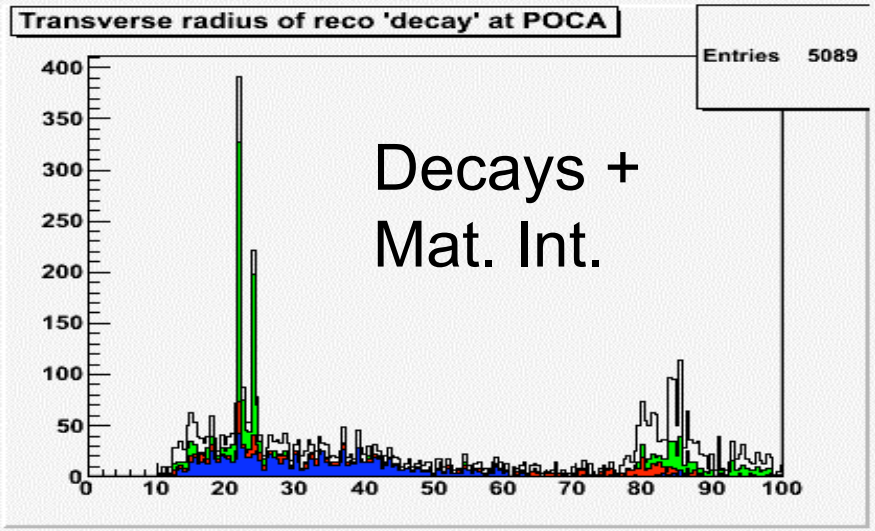




Identifying Duplicate Tracks





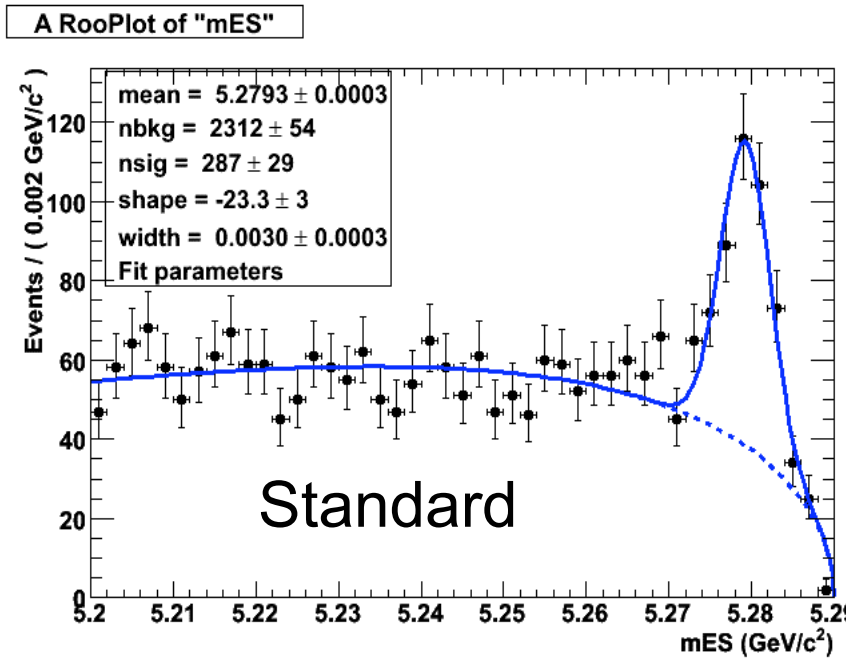


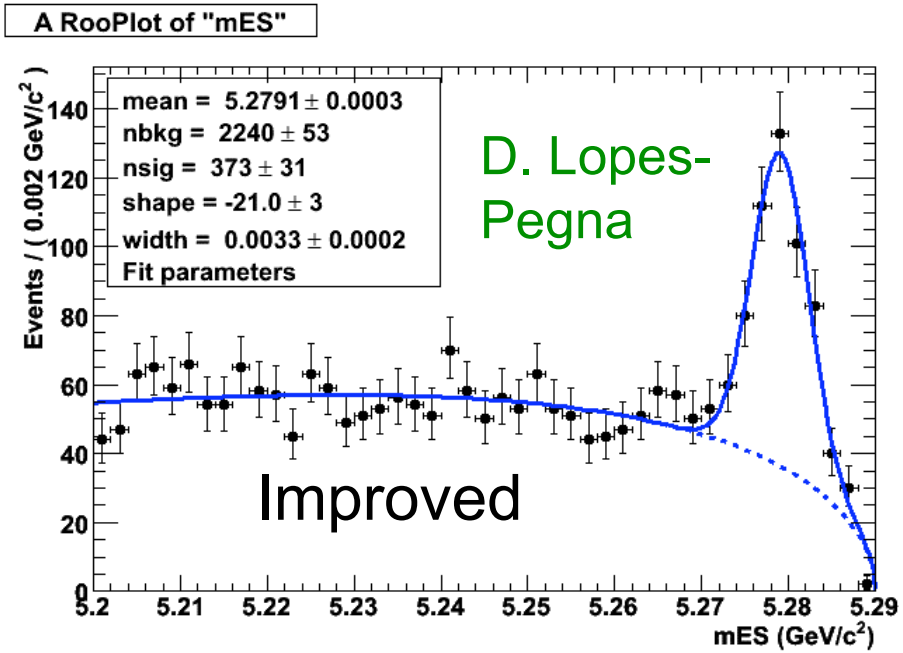
Transverse Radius (cm)

- **Rejects ~1 fake/duplicate track/event**
  - **~30% efficient**
  - **Removes < 1/1000 physics tracks**

Tracking Improvement Results

- 1→10% increase in good track eff.
- 10→20% decrease in backgrounds
- Net 30% increase in inclusive hadronic B reconstruction eff.
  - —20% improvement in S/N





Tracking Improvement Status

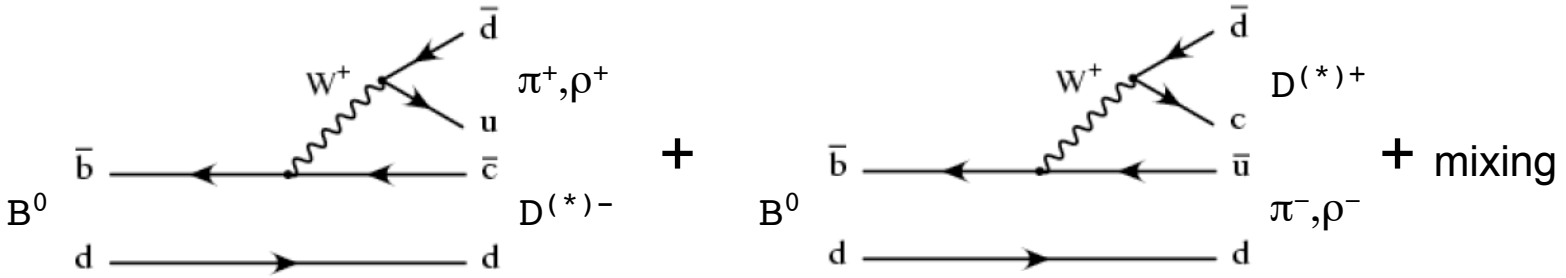
- Principle service responsibility of LBL staff/students/postocs
  - —Coordination
  - —Algorithm development
    - M. Battaglia, D. Brown, E. Prencipe, G. Lynch, T. Tanabe,
  - —Physics selection and Validation
    - D. Lopes
- Development and testing going on now
- Full Deployment in Summer 2006
  - —Full pass through existing BaBar data
  - —Apply Fixes, remake physics selections (skim)
    - Inside standard Analysis job
    - Tracking fixes add ~5% CPU burden

LBNL BaBar Analysis Efforts

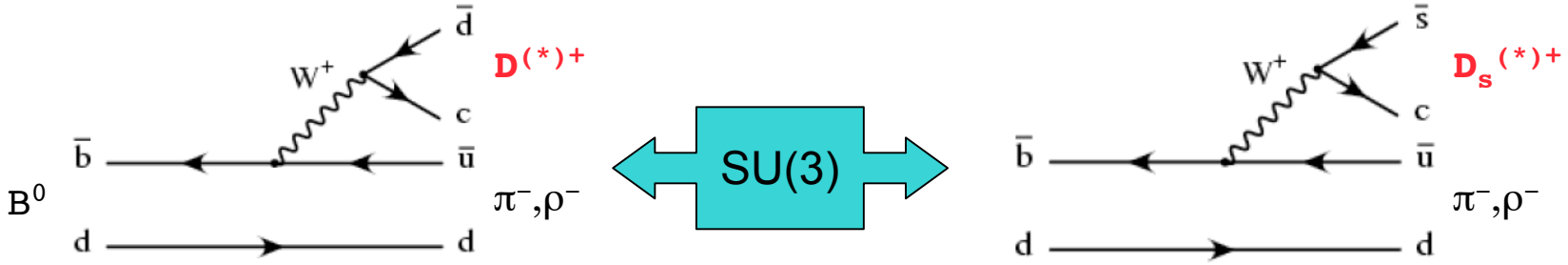
- CP-violation
- Rare charmless B decays
- B→Vector Vector decays
- Semi-leptonic B decays

Helping constrain γ: $B^0 \to D_s^{(*)}\pi/\rho/K$
(Orimoto, Suzuki, Troost, Kolomensky)

- **CP asymmetry in $B^0 \to D^{(*)}\rho,\pi$ sensitive to sin(2β+γ)**



- **Small interference term depends on ratio $|V_{ub}/V_{cb}|^2$ and hadronic physics: needs to be measured to extract sin(2β+γ) from CP asymmetry**
- **Rates from SU(3) related D_s modes**

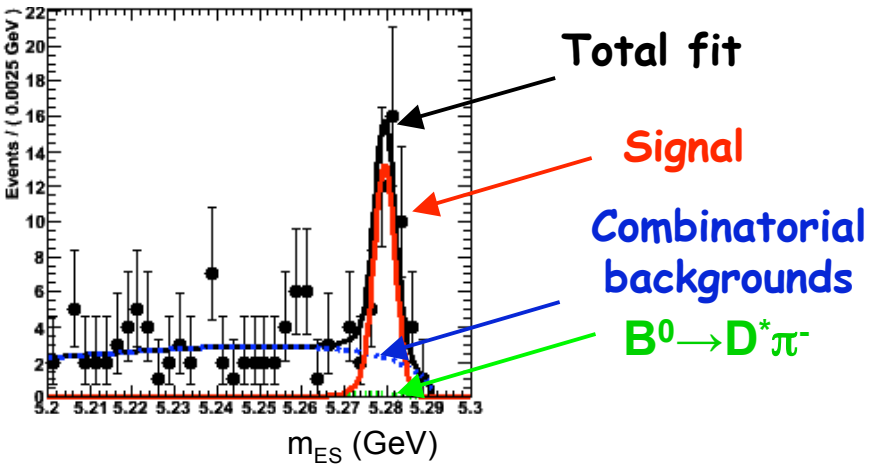


- ~20% error from SU(3) breaking; limit theory error by measuring $D_s^{(*)}K$
- So far, only $D_s\pi/K$ have been seen by BaBar and Belle

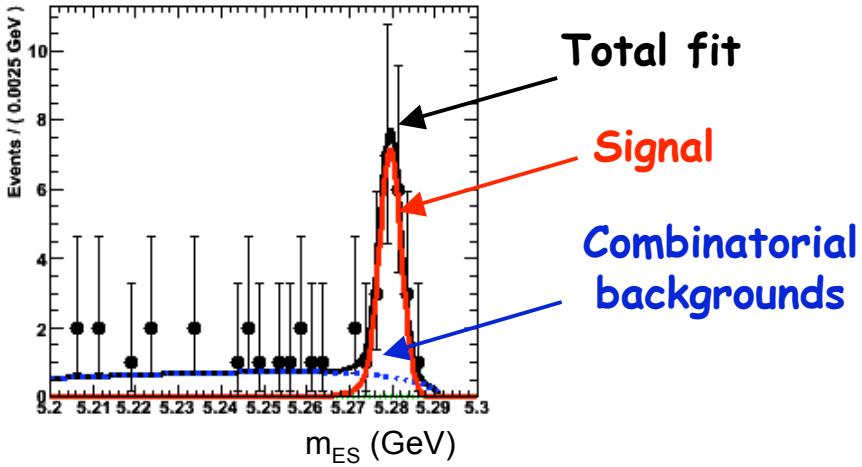
Observation of $D_s^{(*)}\pi$, $D_s^{(*)}K$

- **New analysis based on 230M B decays**
- **Preliminary results for Moriond QCD, to be published this spring**
- **Improved measurements of $D_s\pi$ and D_sK decays**
  - $\mathcal{B}(B^0 \to D_s^+ \pi^-)$ = (x.x ± y.y ± z.z)x10^{-5} (5σ significance, first observation)
  - $\mathcal{B}(B^0 \to D_s^- K^+)$ = (x.x ± y.y ± z.z)x10^{-5} (9σ significance)
- **New measurements of $D_s^*\pi$ and D_s^*K decays**
  - $\mathcal{B}(B^0 \to D_s^{*+} \pi^-)$ = (x.x ± y.y ± z.z)x10^{-5} (6σ significance, first observation)
  - $\mathcal{B}(B^0 \to D_s^{*-} K^+)$ = (x.x ± y.y ± z.z)x10^{-5} (5σ significance, first observation)

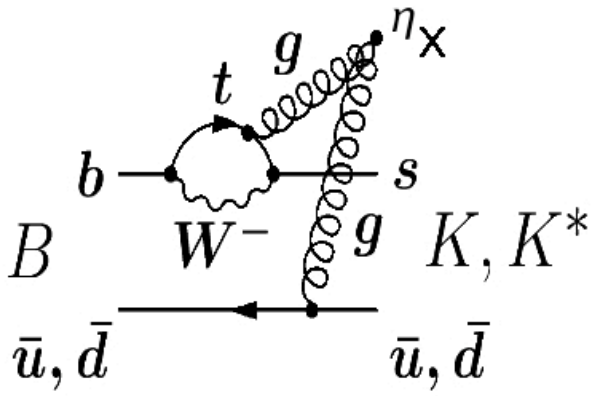
$B^0 \to D_s^{*+} \pi^-$



$B^0 \to D_s^{*-} K^+$



$B^{\pm} \rightarrow \eta_x K^{\pm}$ (G. Kukartsev)



$B^{\pm} \rightarrow (K_s K^{\pm}\pi^{\mp})K^{\pm}$
$\pi^{\pm}\pi^{\mp}$

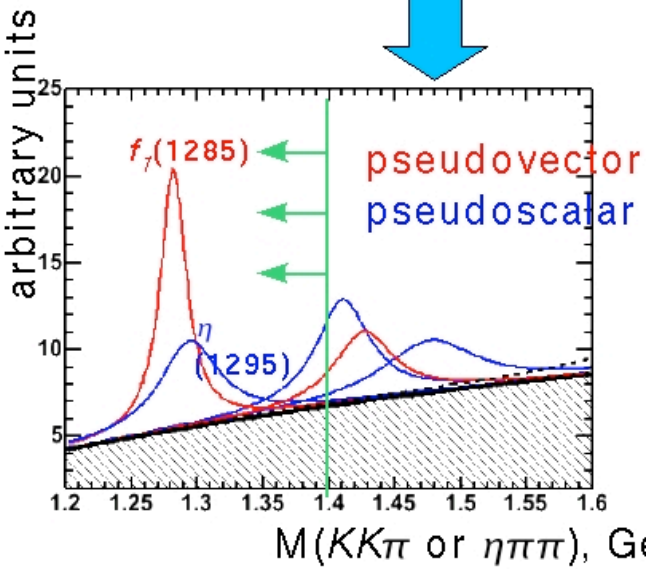
$B^{\pm} \rightarrow (\eta\pi^{\pm}\pi^{\mp})K^{\pm}$,
$\gamma\gamma$

Any of these could be gluonium, or evidence of new physics (through a loop diagram)

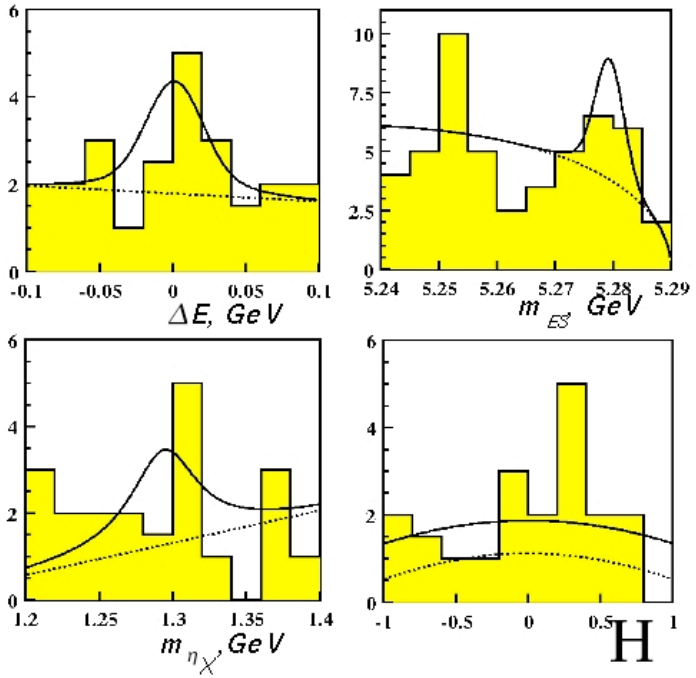
Fit searches for:

f1(1285)
η(1295)
η(1405)
f1(1420)
η(1475)K
qq background
bb background

m_{ES}
ΔE
Fisher
$m_{\eta X}$
$\cos(\theta_{helicity})$



$B^{\pm} \rightarrow \eta_x K^{\pm}$ (G. Kukartsev)



$B^{\pm} \rightarrow (\eta\pi^{\pm}\pi^{\mp})K^{\pm}$, $\eta \rightarrow \gamma\gamma$

Blinded projection plots

Simultaneous Maximum Likelihood fit for $M_{\eta} < 1.4$ Gev

$N_{\eta(1295)K^+} = 14 \pm 9, \quad N_{f_1(1295)K^+} = 1 \pm 6$

$BR(B^+ \rightarrow \eta(1295)K^+) \times BR(\eta(1295) \rightarrow K^0 K^- \pi^+) < 2.1 \times 10^{-6}$, 90% C.L.

$BR(B^+ \rightarrow f_1(1285)K^+) \times BR(f_1(1285) \rightarrow K^0 K^- \pi^+) < 1.2 \times 10^{-6}$, 90% C.L.

$BR(B^+ \rightarrow f_1(1285)K^+) < 2.0 \times 10^{-5}$, 90% C.L.

Charmless B→V V decays

Expect small BF (~10^{-6})

Expect longitudinal polarization $f_L \sim 1 (-4\, m_V^2 / m_B^2)$

	BF (X 10^{-6})		f_L	
	BaBar	**Belle**	**BaBar**	**Belle**
$\rho^0\rho^+$	$22.5^{+5.7}_{-5.4}\pm5.8$	$31.7\pm7.1^{+3.8}_{-6.7}$	$0.97^{+0.03}_{-0.07}\pm0.04$	0.95±0.11±0.02
$\rho^+\rho^-$	30 ±4 ±5	$24.4\pm2.2^{+3.8}_{-4.1}$	$0.99\pm0.03^{+0.04}_{-0.03}$	$0.951^{+0.033}_{-0.039}{}^{+0.029}_{-0.031}$
$\rho^0\rho^0$	< 1.1	-	-	-
ρ^0K^{*+}	$10.6^{+3.0}_{-2.6}\pm2.4$	-	$0.96^{+0.04}_{-0.15}\pm0.04$	-
ρ^0K^{*0}	-	< 2.6	-	-
ρ^+K^{*0}	$17.0\pm2.9^{+2.0}_{-2.8}$	8.9±1.7±1.2	0.79±0.08±0.04	$0.43\pm0.11^{+0.05}_{-0.02}$
ρ^-K^{*+}	< 24	-	-	-
φ^0K^{*+}	$12.7^{+2.2}_{-2.0}\pm1.1$	$6.7^{+2.1}_{-1.9}$+0.7-1.0	0.46±0.12±0.03	0.52±0.08±0.03
φ^0K^{*0}	9.2±0.9±0.5	$10.0^{+1.6}_{-1.5}$+0.7-0.8	0.52±0.05±0.02	0.45±0.05±0.02

Measured at LBL recently

Measured at LBL on Run 1-2 data (published in 2003)

Tree dominated

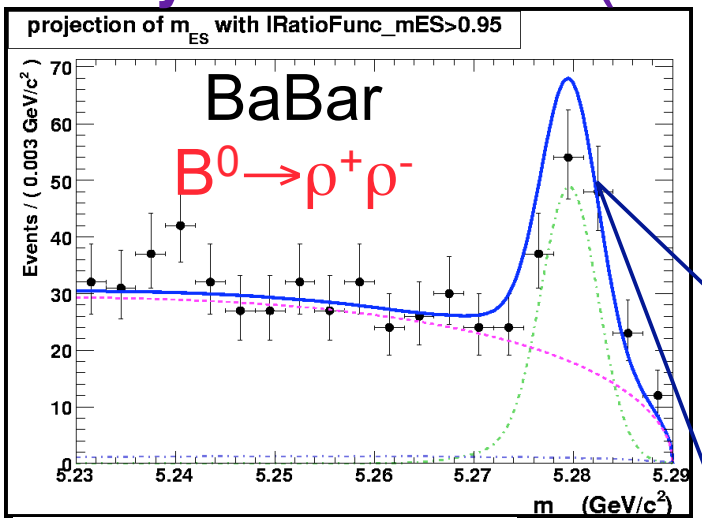
Penguin dominated

Pure penguin

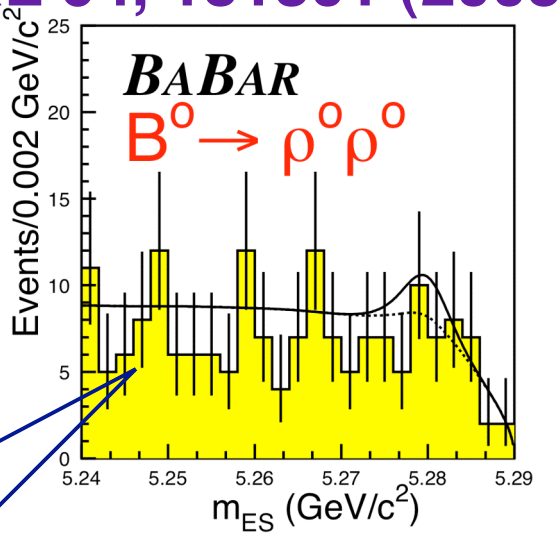
Extracting Δα from B→ρ ρ
(Gritsan, Groysman, Mir)

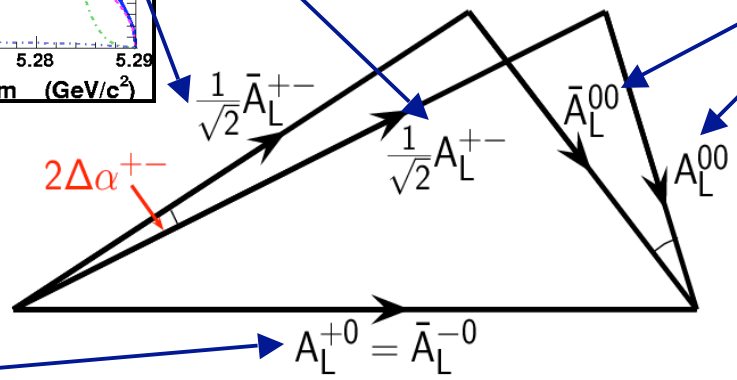
Berkeley Lab

Groysman Thesis (2006)



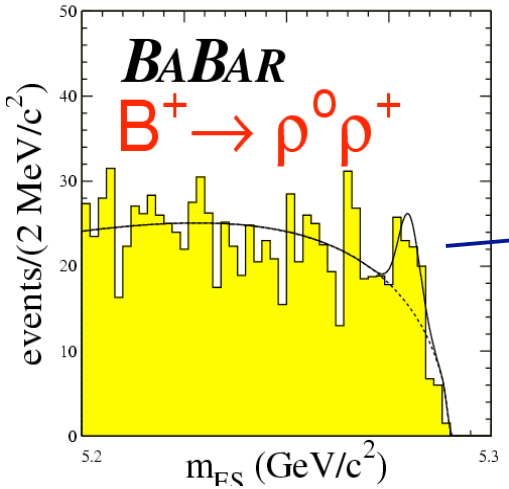
PRL 94, 131801 (2005)





BF(B→ρ⁰ρ⁰) < 1.1X10⁻⁶

BF(B→ρ⁺ρ⁻) ~ 30X10⁻⁶

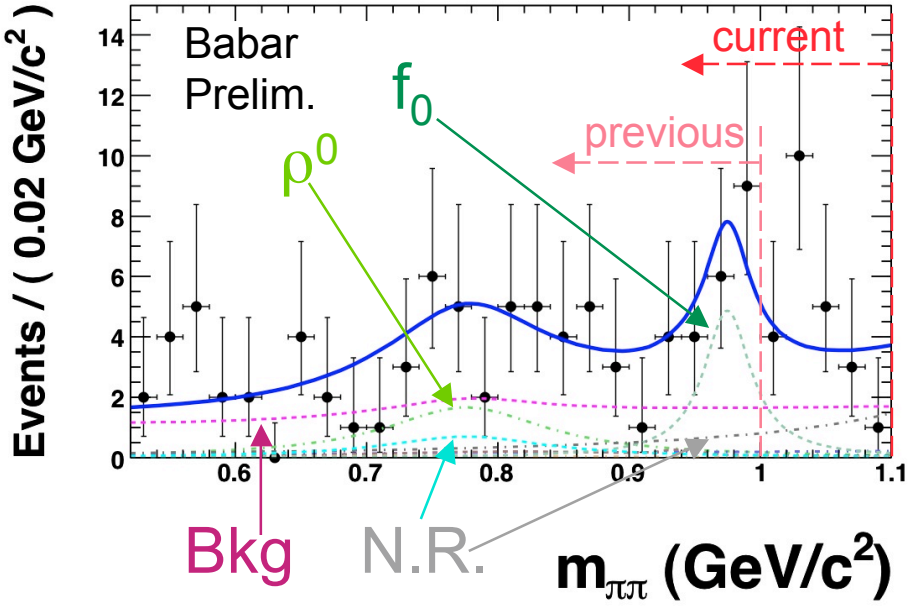


$\alpha_{\rho\rho} = 96^{\circ} \pm 10(\text{stat}) \pm 4(\text{syst.}) \pm 11(\Delta\alpha)$

PRL 91, 171802 (2003)

$B^+ \to \rho^0 K^{*+}$, $f_0 K^{*+}$ Measurement Update (Mir)

- Increased statistics
  - — 210 fb^{-1} vs 81 fb^{-1}
- Opened $\pi\pi$ mass window
- Fit for ρ^0 and f_0
- Explicitly fit non-resonant $K\pi$ and $\pi\pi$ components
- Improved model of B bkgs
  - — Explicit charmless mode
- Max. Likelihood Fit for BF, polarization, charge asymmetry
  - — m_{ES}, ΔE, F, $m_{K\pi}$, $m_{\pi\pi}$, $\cos\theta_{K\pi}$, $\cos\theta_{\pi\pi}$

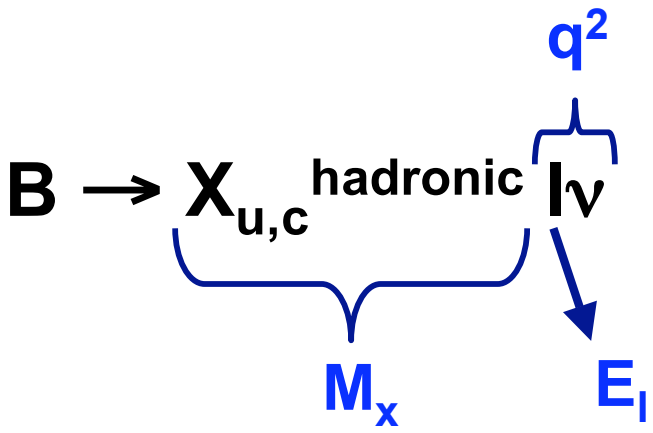


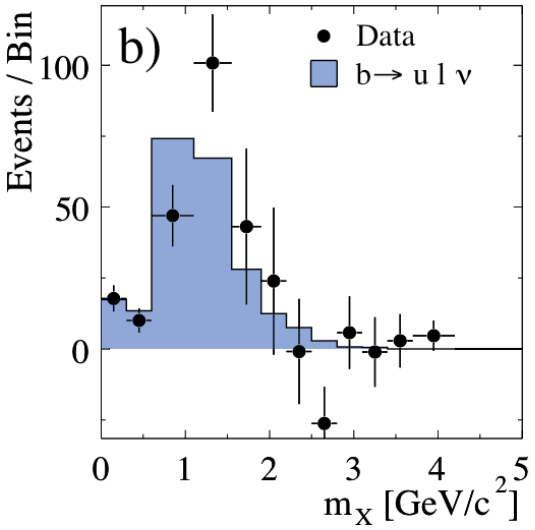
$B(B^+ \to \rho^0 K^{*+}) = (\quad {}^{+1.9}_{-1.8} \pm 0.9) \times 10^{-6}$ $fL(B^+ \to \rho^0 K^{*+}) = (\quad {}^{-0.22}_{-0.20} \pm 0.08$

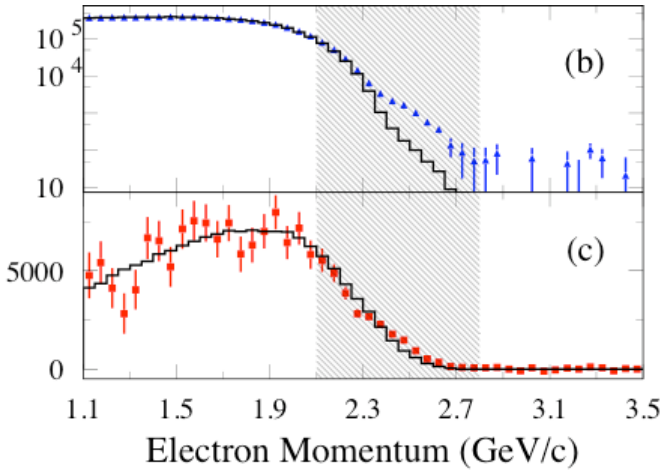
(~2 sigma significance)

$B(B^+ \to f_0 K^{*+}) = (\quad {}^{+1.4}_{-1.3} \pm 0.6) \times 10^{-6}$

V_{ub} from inclusive semi-leptonic decays (Tackmann)



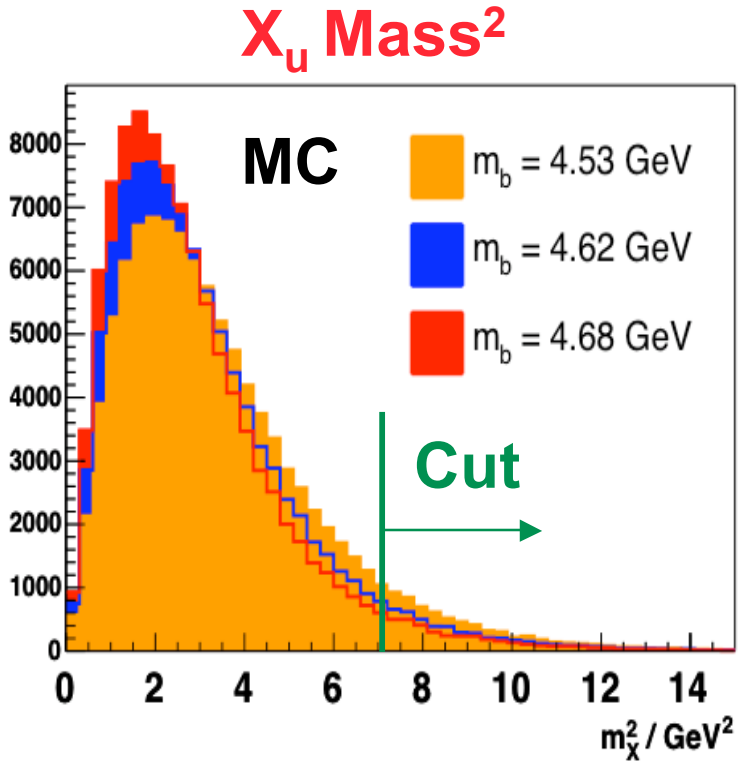




LBL involvement

Variable	V_{ub} (X10^{-3})	Exp. Error	HQE param error (m_b,…)	Other theory error
M_x	4.77	±0.4	+0.68-0.43	±0.13
M_x-q^2	4.92	±0.53	±0.46	—
q^2-E_l	3.95	±0.27	+0.58-0.42	±0.25
E_l	4.44	±0.25	+0.42-0.38	±0.22

Constraining m_b with M_x^2 moments (Battaglia,Tackmann)



- Hadronic moments sensitive to m_b
  - Using HQET formalism
- b→u hadronic moments 10x more sensitive to m_b than b→c hadronic moments
  - HQE depends on m_b-m_q
- b→u/ b→c rate ~ 1%
  - ~comparable total uncertainty on m_b from moments measurements

- Compare m_b from b→u, b→c moments
  - Test underlying HQE formalism
- Vary cuts on M_X^2 and compare moments against HQE prediction
  - Test where nonperturbative effects become important
- Results in preparation for summer 2006

B → Charm Inclusive Studies

Decay Mode	Branching Fraction
$B^0 \to l^+ \nu_l$ + anything	10.5 ± 0.8 %
$B^0 \to D^*(2010) - l^+ \nu_l$	5.44 ± 0.23 %
$B^0 \to D^- l^+ \nu_l$	2.14 ± 0.20 %
$B^0 \to D^{**} l^+ \nu_l$	??
$B^0 \to D^{*-} n\pi l^+ \nu_l$	??
$B^0 \to \bar{\Lambda}_c^- X l^+ \nu_l$	??

Decay Mode	Branching Fraction
$B^+ \to l^+ \nu_l$ + anything	10.2 ± 0.9 %
$B^+ \to D^*(2007)^0 l^+ \nu_l$	6.5 ± 0.5 %
$B^+ \to \bar{D}^0 l^+ \nu_l$	2.15 ± 0.22 %
$B^+ \to \bar{D}_1(2420)^0 l^+ \nu_l$	0.56 ± 0.16 %
$B^+ \to D^{*0} n\pi l^+ \nu_l$	??
$B^+ \to \bar{\Lambda}_c^- X l^+ \nu_l$	??

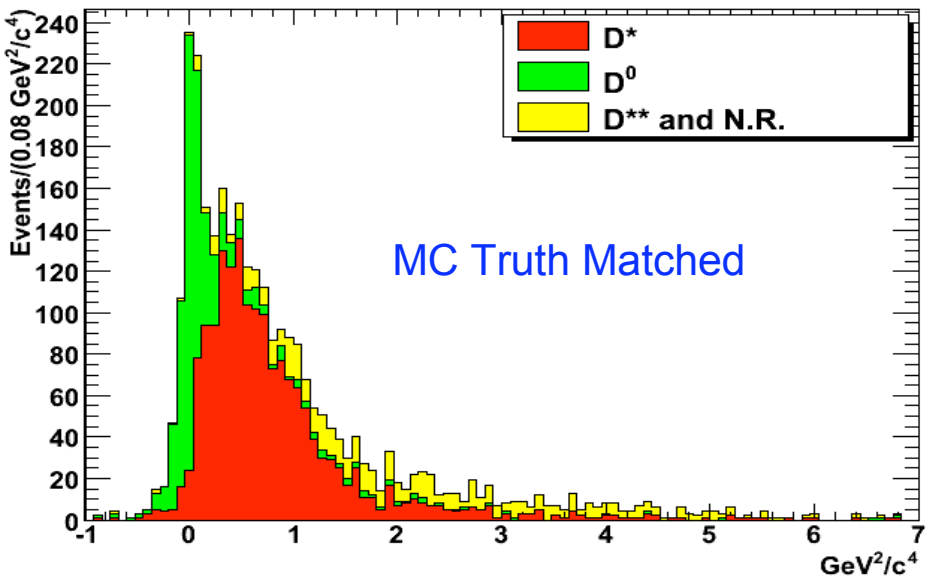
- Exclusive ($B \to X_c l\nu$) and inclusive ($B \to D^{(*)} l\nu$) measurements disagree
- Some (expected) decay modes yet to be discovered
- Many semileptonic B→charm decays have large uncertainties
  - Especially $B \to D^{**} l\nu$, $B \to D^{(*)}\pi l\nu$
  - Dominant background in V_{cb} from $B \to D^* l\nu$
  - Dominant background systematic in V_{ub} measurements

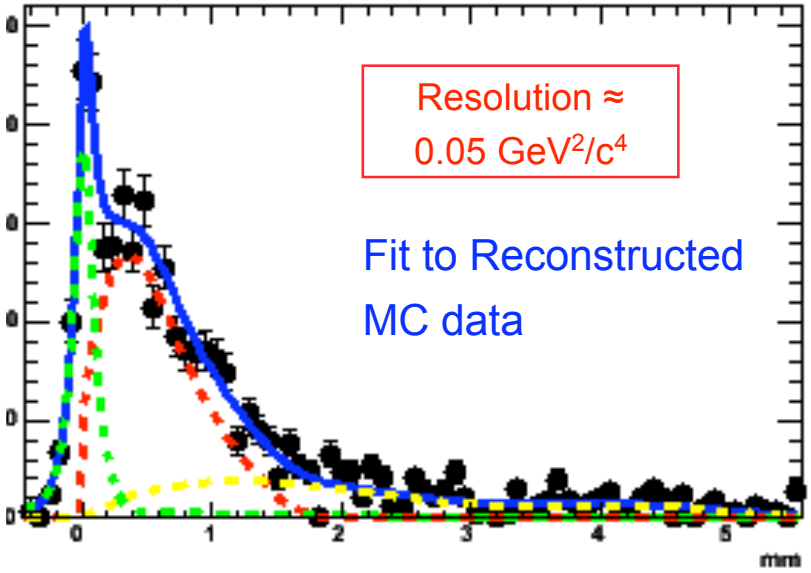
$B \to (D, D^*, D^{**}, D^{(*)}\pi) l\nu$ with Hadronic Tags

D. Lopes

- Fully reconstruct 1 B from $\Upsilon \to BB$ in purely hadronic mode (~1/1000)
- Reconstruct $B \to DXl\nu$ inclusively on recoil
  - Explicitly reconstruct D, lepton
  - Resolve states using missing mass, lepton momentum, …
- Probability Density Functions extracted from data
  - Clean exclusive samples
- Monte Carlo simulation estimates ~< 5% error on relative fractions
- First results being prepared for summer conferences

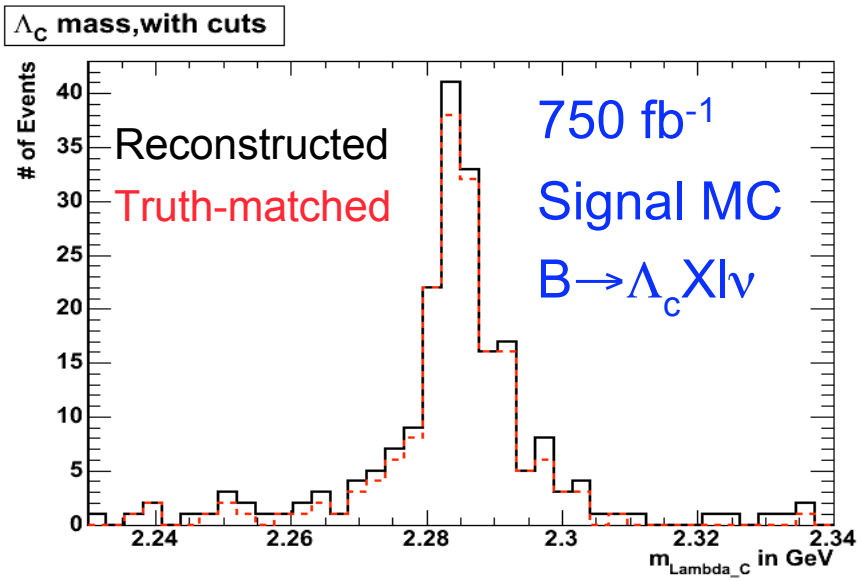
MissNu2

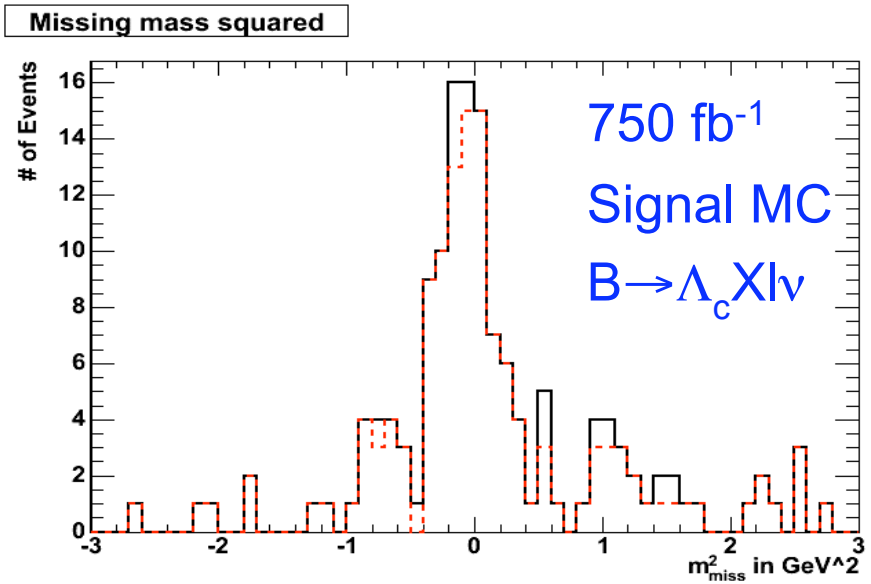




$B \to \Lambda_c X l \nu$ with Hadronic Tags
(D. Lopes, C.Anders)

- Fully reconstruct 1 B from $\Upsilon \to BB$ in purely hadronic mode (~1/1000)
- Reconstruct $B \to \Lambda_c X l \nu$ inclusively on recoil
  - Reconstruct Λ_c ($pK\pi$ decay mode), lepton
  - Tag Semileptonic decay using Λ_c invariant mass and missing mass in the event
- Decay modes never observed
- First results by end of 2006

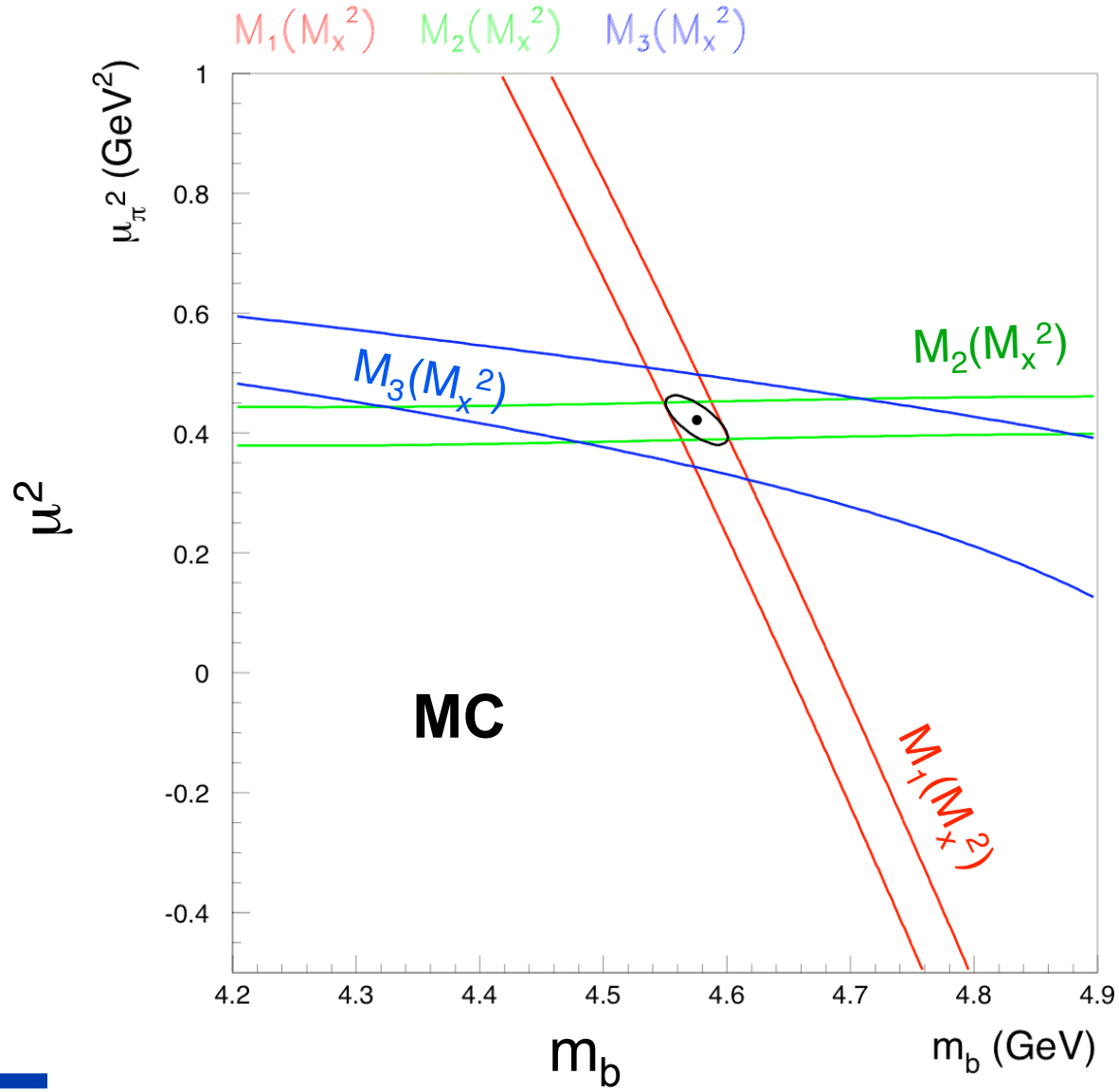




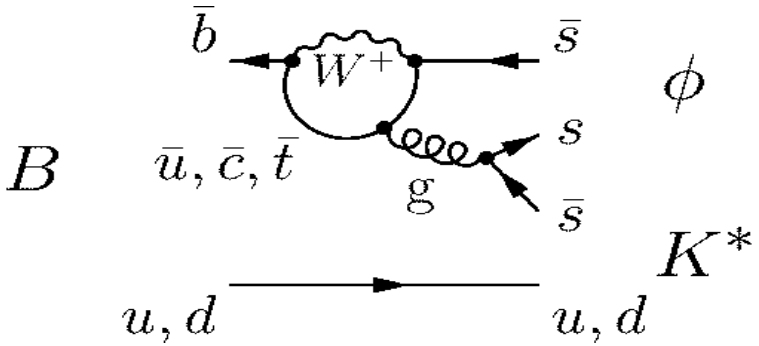
Conclusions

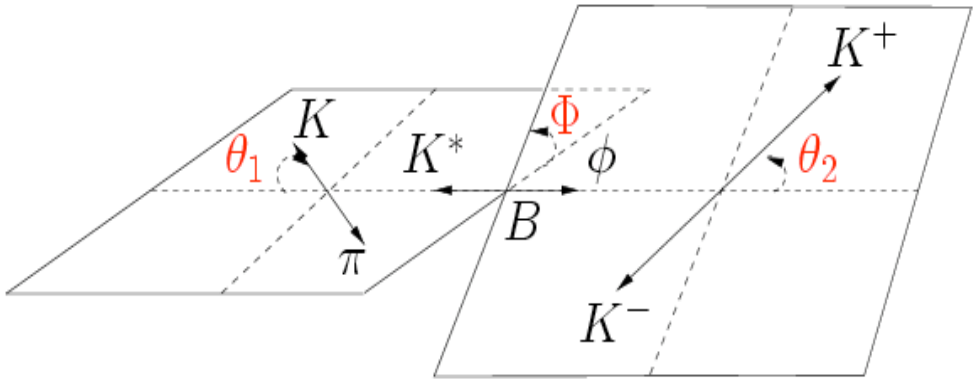
- LBNL continues to participate in BaBar
  - —Tracking improvements help all analyses
  - —Local analyses exploit the BaBar data
- Students, staff and faculty remain interested in BaBar
  - —Large past investments in construction, operations
  - —1.5 more years of running likely
    - ~ 1 attobarn^{-1} final sample
  - —Complementary physics to hadron colliders
  - —Many years of analysis after shutdown
    - Theses for students working on ILC Detector R&D

Constraining $m_b + \mu^2$ with M_x^2 moments (Battaglia,Tackmann)



B → φ K* Polarization Puzzle (Gritsan)





BF ~10^{-5}

Extracts from full CP analysis

PRL 93, 231804 (Dec. 2004)

- **Mixed polarization**
  - **Additional SM process?**
  - **New Physics?**
- **Non-zero (strong) phase**
  - **Contrary to factorization**